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十勝港での圧力センサーによる2007年ペルー津波の観測

Observation of the 2007 Peru tsunami at Tokachi port by a pressure gauge

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Abstract

A distant tsunami being generated in Peru on 15 August 2007 was observed at Tokachi port, Hokkaido, Japan in a process of seiche observation using a pressure gauge. The sea level oscillation for 18 hours including sea conditions before and after the arrival was decomposed into the spectra. As the result we found that dominant periods varied from 19 minutes to 56 minutes for time domains before the arrival and after the arrival, respectively. These dominant periods are interpreted as ones of the port and the shelf as estimated from Merian's formula. The former one of 19 minutes is almost equal to one - third of the latter one of 56 minutes. Before the arrival the most dominated period was 19 minutes, and after the arrival it was displaced to 20 minutes occupying a second highest peak following the most dominated period of 56 minutes. After the arrival a natural oscillation of the port was excited as a resonance to first higher mode of the shelf oscillation.

Key Words : Peru tsunami, pressure gauge, dominant period, seiche,Tokachi port

Introduction

Data of dominant periods in seiche, collected from various bays, were proved to be useful to estimate a period of tsunami under a condition of combining the amplification (Abe, 2005). It shows that resonance is an important factor to understand amplification of tsunami. It is interesting to use a period dependence of bay and port for determining the period of tsunami. To determine the period dependence we need much data of different seiche period. A portable pressure gauge is an important instrument to collect much data. It is important to observe seiche not only at bays but also at ports to study tsunami amplification.

Pacific coast of Japan frequently receives a distant tsunami generated in South America. Hatori (1968) studied a percentage of tsunami propagating to Japan from South America in all the tsunamis generated in South America, and showed a lower limit being within 7.7 - 8.0 in earthquake magnitude from the earthquake magnitude dependence. Two Peru tsunamis of 1966 and 1974 arrived at Hokkaido are reported in tsunami collections edited by Sapporo District Observatory (1986).

Observation of tsunami by a pressure gauge

It had been planed to obtain data of seiche at bays and ports in south east Hokkaido using a pressure gauge.According to the plan an observation of seiche was conducted at Tokachi port in Hokkaido,

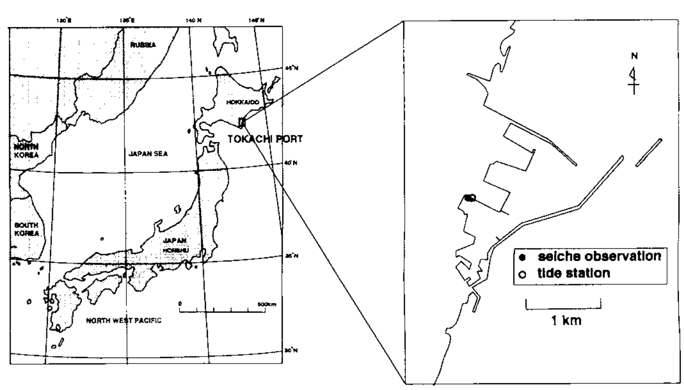

Fig.1　Observation point of seiche (solid circle) and Tokachi tide station (open circle).

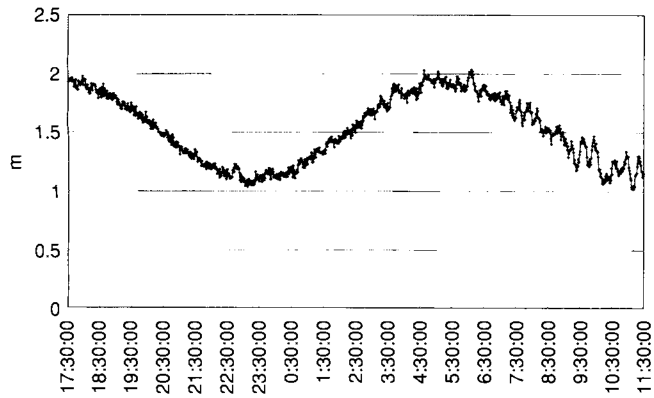

Fig.2 Sea level detected at the seiche observation point. Time is Japan Standard Time (JST).

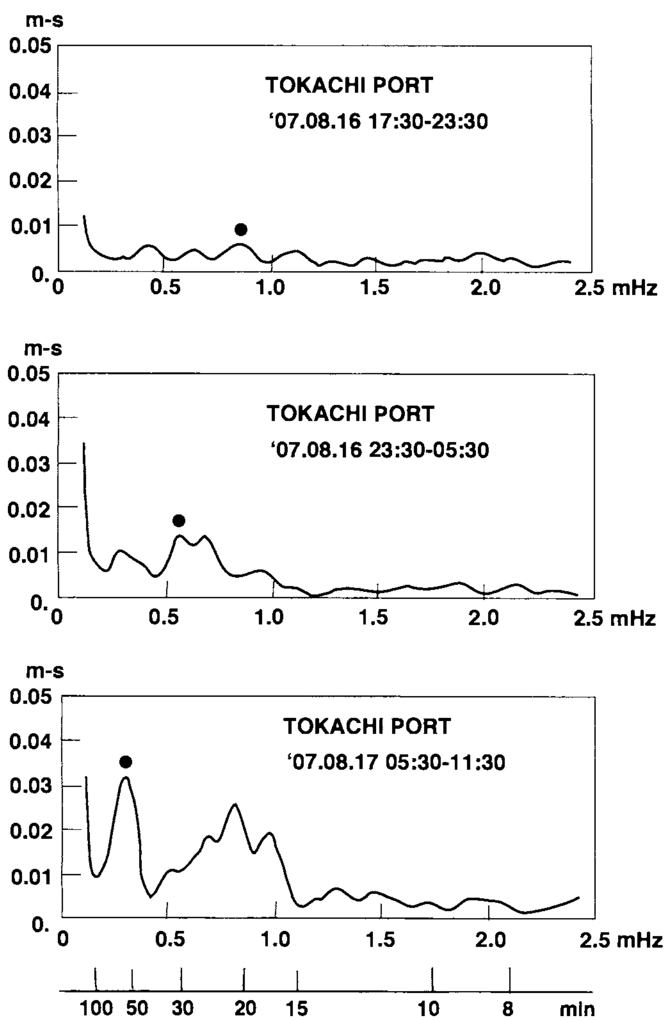

Fig.3 Amplitude spectra for three stages. Solid circles are dominant periods. First (top), second (middle) and third (bottom) stages

Japan on August 16, 2007 (Figure 1).At that time news of a large earthquake of $M_w = 8.0$ generated in Peru, South America was brought. It had an origin time of 23h 40m 57.8s on August 15, 2007 (UT) with hypocenter of S13.386°, W76.603° and depth of 39 km. As the result observation of the tsunami was expected in the port. We started to observe the seiche at 17:30, August 16 (JST) (8:30 UT) before the arrival and continued the observation until 11:30, August 17 after the arrival.

Thus, time variation of sea level, sampled with time interval of 1 minute, was obtained as shown in Figure 2. It was difficult to determine an initial arrival of tsunami from the waveform. Since the measuring point is located in front of Tokachi tide station (N42° 18',E143° 19') as shown in Figure 1, the epicentral distance is estimated to be 15005 km. Referring the 1960 Chilean tsunami propagating across the Pacific Ocean, we can obtain an average apparent velocity of 198 m/s (Berkman and Symons, 1961). When we apply the velocity to this tsunami, we can calculate a travel time of 21h 03m. Adding this time to the origin time, we obtain an expected arrival time of 5h 44m, August 17 (JST) was obtained.

We divided the time history into three stages of every 6 hours. First two stages are included in tsunami free stage and the third one is included in tsunami stage.

Spectra of the tsunami

Amplitude spectra were obtained for the three stages by using the method as Abe (2005), which is shown in Figure 3. In the first stage the most dominant period is 19 minutes with the amplitude of 0. 0065 m - s. The dominance is not so notable in comparison with other spectral peaks. On the other hand the most dominant period shifted to 56 minutes with the amplitude of 0.0323 m - s in the third stage after the arrival. The period and the amplitude increased by three and five times, respectively. It is concluded that the increase was attained by the arrival. In the third stage period component of 20 minutes also developed itself. The amplitude is larger than that of the dominant period of 19 minutes. It is notable that the period is approximately equal to the dominant

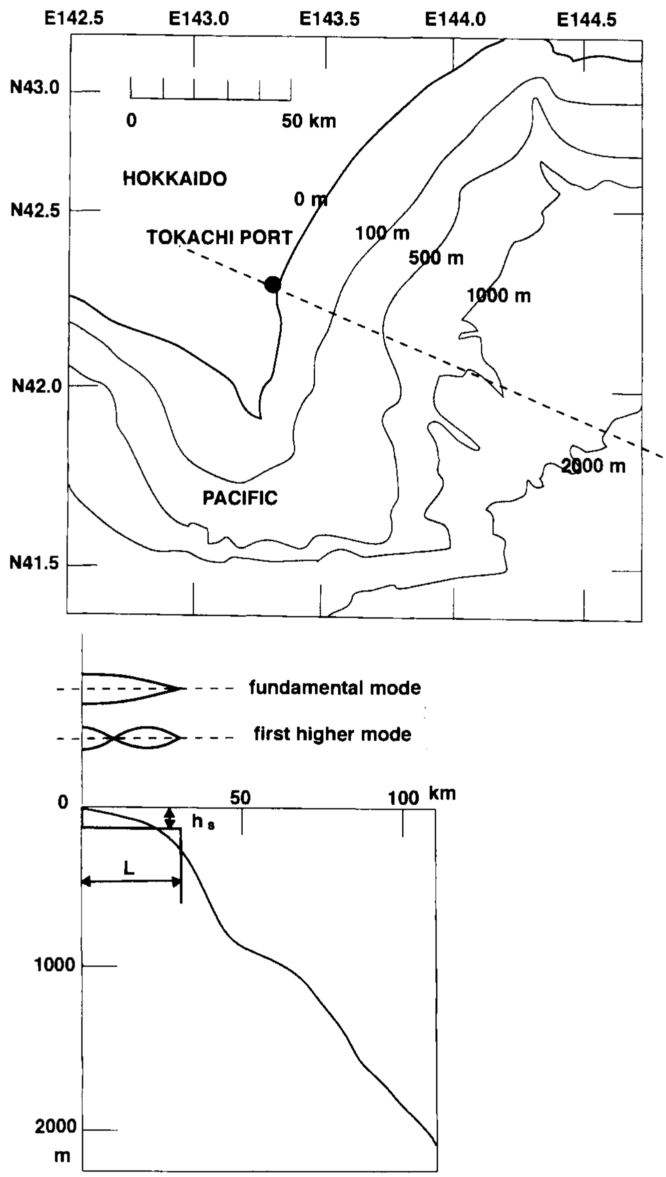

Fig.4 Sea bottom topography around Tokachi port (top) and the profile along a dotted line through the port (bottom). Shelf oscillations are modeled in the profile.

period of the first stage.

We will add a consideration to explain the excitations. Using Merian's formula we will represent a period of shelf oscillation T_S like as

$$T_S = \frac{4L}{\sqrt{gh_S}}$$

in which L is the width, g is gravitational acceleration and h_S is sea depth of the shelf. As for the shelf in front of Tokachi port we assume the width L of 30 km, and sea depth h_S of 130 m as shown in Figure 4. From the model we obtain a period T_S of 56 minutes. This is fundamental mode of the shelf oscillation. The first higher mode has a period of 19 minutes. It is concluded that the most dominant period in the third stage is the fundamental mode and the second dominant period of 20 minutes in the third stage almost corresponds to the first higher mode in the shelf oscillation.

In the next step we notice harbor oscillation. Harbor respond to long wave and as the seiche period we can apply Merian's formula. The period T_h is expressed as

$$T_h = \frac{4l}{\sqrt{gh_h}}$$

in which l is the length and h_h is the sea depth. Referring a home page of Obihiro Development and Construction Office (http://www.ob.hkd.mlit.go.jp/hp/kou/kou4.html), an average sea depth h_h of 7 m, and the length l of 2.3 km are assumed. From this assumption we obtain a period T_h of 19 minutes.

Thus, we can explain the dominant period of 19 minutes in the first stage as a fundamental mode of the harbor oscillation. This mode was one of the modes which is easily excited in a calm sea condition and observed as the most dominant period in the first stage. Since the period is approximately equal to the first higher mode of the shelf oscillation, it was also excited by tsunami. It formed the second highest peak of the tsunami. This mode was amplified by a synchronization of the harbor oscillation to the shelf oscillation. It is understood as a resonance of the port to the tsunami.

Sea level observed at Tokachi tide station

In relation to measuring instrument we notice tide gauge record observed at Tokachi tide station. The station was operating on August 16 - 17, 2007 nearest to the seiche observation point (Figure 1) and the raw record is shown in Figure 5. Comparing this figure with Figure 2 we understand a difference of response. The tide station records sea level on a float in the well, which is connected to the sea with an intake pipe. The geometry is as follows (Shuto, 1988) : Diameters of well and intake pipe are 1.2 m and 0.1 m, respectively. Length of the intake pipe is 2.8 m. The intake pipe has a role to decrease short period components in the sea level oscillation.

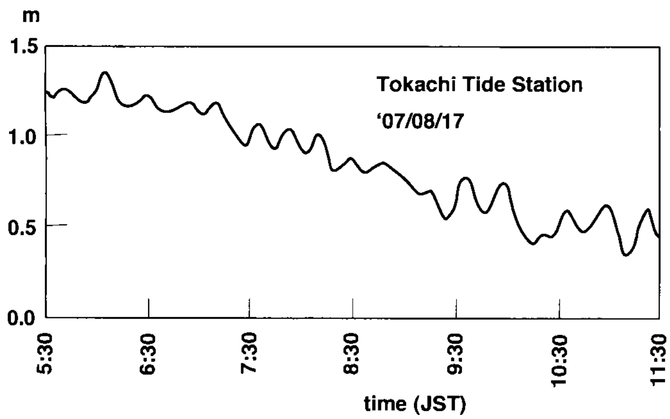

Fig.5 Sea level observed at Tokachi tide station. Time is Japan Standard Time (JST).

A pressure gauge detects pressure of water and transforms the pressure into the sea level. The sensor is nakedly hung in a quay. The sea level is detected directly. Thus, we recognize difference of the response. We can understand that tide gauge records rounded wave and pressure gauge records sharp wave as shown in Figure 5.

Discussion

The epicenter is almost located on a boundary between the Pacific Ocean and South American Continent in Peru. This fact means that tsunami was generated on the shelf. A numerical simulation on a home page of Tohoku University, Civil Engineering (http://www.tsunami.civil.tohoku.ac.jp/hokusai2/disaster/07 Peru/zmax case0.jpg) showed a radiation pattern directing toward south west direction, which corresponds to an azimuth direction of north - west in the coast line. This directivity suggests the weak radiation toward Japan. This generation mechanism is related to a tsunami with the small initial motion and with the excitation of shelf oscillation.

Summary

A distant tsunami from Peru was observed at Tokachi port using a pressure gauge. The spectral analysis revealed that a shelf oscillation and a harbor oscillation were excited by the tsunami. The dominant periods of the shelf and the port are 56 and 19 minutes, respectively. The harbor oscillation was excited as first higher mode of the shelf oscillation.

Acknowledgement

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References

Abe,K., Tsunami resonance curve on dominant periods observed at bays, in "Tsunamis: Case studies and recent developments", ed. by K. Satake,Springer Publishing, 97-113, 2005.

Berkman,S.C. and J.M. Symons, The tsunami of May 22, 1960 as recorded at tide stations, U.S.Dept. Commerce, 1-79,1961.

Hatori,T., Study of distant tsunamis along the coast of Japan. Part 2, Tsunamis of South American origin. Bull. Earth. Res. Inst., 46, 345-359, 1968.

Sapporo District Meteorological Observatory, Earthquake Tsunamis in Hokkaido, 1-189, 1986, (in Japanese).

Shuto,N., Characteristic response of tide well, in "Generation and amplification mechanism, destructive force of Nihonkai - Chubu Earthquake Tsunami", Report of Grant - in - Aid from Ministry of Education, 1 - 324, 1988 (in Japanese).